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Unassigned 10/069479

INTERNATIONAL APPLICATION NO.	INTERNATIONAL FILING DATE	PRIORITY DATE CLAIMED
PCT/JP00/05599	**August 22, 2000**	**August 31, 1999**

TITLE OF INVENTION
OFDM COMMUNICATION APPARATUS AND PROPAGATION PATH ESTIMATION METHOD

APPLICANT(S) FOR DO/EO/US
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Applicant herewith submits to the United States Designated/Elected Office (DO/EO/US) the following items and other information:

1. ☒ This is a **FIRST** submission of items concerning a filing under 35 U.S.C. 371.
2. ☐ This is a **SECOND** or **SUBSEQUENT** submission of items concerning a filing under 35 U.S.C. 371.
3. ☒ This is an express request to begin national examination procedures (35 U.S.C. 371(f)). The submission must include itens (5), (6), (9) and (24) indicated below.
4. ☐ The US has been elected by the expiration of 19 months from the priority date (Article 31).
5. ☒ A copy of the International Application as filed (35 U.S.C. 371 (c) (2))
   - a. ☐ is attached hereto (required only if not communicated by the International Bureau).
   - b. ☒ has been communicated by the International Bureau.
   - c. ☐ is not required, as the application was filed in the United States Receiving Office (RO/US).
6. ☒ An English language translation of the International Application as filed (35 U.S.C. 371(c)(2)).
   - a. ☒ is attached hereto.
   - b. ☐ has been previously submitted under 35 U.S.C. 154(d)(4).
7. ☐ Amendments to the claims of the International Application under PCT Article 19 (35 U.S.C. 371 (c)(3))
   - a. ☐ are attached hereto (required only if not communicated by the International Bureau).
   - b. ☐ have been communicated by the International Bureau.
   - c. ☐ have not been made; however, the time limit for making such amendments has NOT expired.
   - d. ☐ have not been made and will not be made.
8. ☐ An English language translation of the amendments to the claims under PCT Article 19 (35 U.S.C. 371(c)(3)).
9. ☒ An oath or declaration of the inventor(s) (35 U.S.C. 371 (c)(4)).
10. ☐ An English language translation of the annexes to the International Preliminary Examination Report under PCT Article 36 (35 U.S.C. 371 (c)(5)).
11. ☐ A copy of the International Preliminary Examination Report (PCT/IPEA/409).
12. ☒ A copy of the International Search Report (PCT/ISA/210).

Items 13 to 20 below concern document(s) or information included:

13. ☒ An Information Disclosure Statement under 37 CFR 1.97 and 1:98.
14. ☒ An assignment document for recording. A separate cover sheet in compliance with 37 CFR 3.28 and 3.31 is included.
15. ☐ A **FIRST** preliminary amendment.
16. ☐ A **SECOND** or **SUBSEQUENT** preliminary amendment.
17. ☐ A substitute specification.
18. ☐ A change of power of attorney and/or address letter.
19. ☐ A computer-readable form of the sequence listing in accordance with PCT Rule 13ter.2 and 35 U.S.C. 1.821 - 1.825.
20. ☐ A second copy of the published international application under 35 U.S.C. 154(d)(4).
21. ☐ A second copy of the English language translation of the international application under 35 U.S.C. 154(d)(4).
22. ☐ Certificate of Mailing by Express Mail
23. ☒ Other items or information:

Ckaim for Priority with PCT/IB/304
PCT/IB/308
PCT/IB/332
PCT/RO/101

U.S. APPLICATION NO. (IF KNOWN, SEE 37 CFR	INTERNATIONAL APPLICATION NO.	ATTORNEY'S DOCKET NUMBER
Unassigned 10/069479	PCT/JP00/05599	L9289.02127

24. The following fees are submitted:.

		CALCULATIONS	PTO USE ONLY
BASIC NATIONAL FEE (37 CFR 1.492 (a) (1) - (5)) :			
☐ Neither international preliminary examination fee (37 CFR 1.482) nor international search fee (37 CFR 1.445(a)(2)) paid to USPTO and International Search Report not prepared by the EPO or JPO	**$1040.00**		
☒ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but International Search Report prepared by the EPO or JPO	**$890.00**		
☐ International preliminary examination fee (37 CFR 1.482) not paid to USPTO but international search fee (37 CFR 1.445(a)(2)) paid to USPTO	**$740.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO but all claims did not satisfy provisions of PCT Article 33(1)-(4)	**$710.00**		
☐ International preliminary examination fee (37 CFR 1.482) paid to USPTO and all claims satisfied provisions of PCT Article 33(1)-(4)	**$100.00**		
ENTER APPROPRIATE BASIC FEE AMOUNT =		**$890.00**	
Surcharge of **$130.00** for furnishing the oath or declaration later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (e)).		**$0.00**	

CLAIMS	NUMBER FILED	NUMBER EXTRA	RATE		
Total claims	10 - 20 =	0	x $18.00	**$0.00**	
Independent claims	6 - 3 =	3	x $84.00	**$252.00**	
Multiple Dependent Claims **(check if applicable).**			☐	**$0.00**	
TOTAL OF ABOVE CALCULATIONS =				**$1,142.00**	
☐ Applicant claims small entity status. See 37 CFR 1.27). The fees indicated above are reduced by 1/2.				**$0.00**	
SUBTOTAL =				**$1,142.00**	
Processing fee of **$130.00** for furnishing the English translation later than ☐ 20 ☐ 30 months from the earliest claimed priority date (37 CFR 1.492 (f)). +				**$0.00**	
TOTAL NATIONAL FEE =				**$1,142.00**	
Fee for recording the enclosed assignment (37 CFR 1.21(h)). The assignment must be accompanied by an appropriate cover sheet (37 CFR 3.28, 3.31) **(check if applicable).**			☒	**$40.00**	
TOTAL FEES ENCLOSED =				**$1,182.00**	
				Amount to be: refunded	$
				charged	$

a. ☒ A check in the amount of **$1,182.00** to cover the above fees is enclosed.

b. ☐ Please charge my Deposit Account No. ________ in the amount of ________ to cover the above fees. A duplicate copy of this sheet is enclosed.

c. ☒ The Commissioner is hereby authorized to charge any additional fees which may be required, or credit any overpayment to Deposit Account No. **19-4375** A duplicate copy of this sheet is enclosed.

d. ☐ Fees are to be charged to a credit card. **WARNING:** Information on this form may become public. **Credit card information should not be included on this form.** Provide credit card information and authorization on PTO-2038.

NOTE: Where an appropriate time limit under 37 CFR 1.494 or 1.495 has not been met, a petition to revive (37 CFR 1.137(a) or (b)) must be filed and granted to restore the application to pending status.

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REGISTRATION NUMBER

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DESCRIPTION

OFDM COMMUNICATION APPARATUS AND PROPAGATION PATH ESTIMATION METHOD

Technical Field

The present invention relates to an OFDM communication apparatus and propagation path estimation method in a digital radio communication system.

Background Art

A main factor of deterioration of transmission characteristics of surface waves along a transmission path is multi-path interference. An OFDM (Orthogonal Frequency Division Multiplexing) transmission system resistant to this multi-path interference is becoming a focus of attention in recent years. This OFDM is a system of multiplexing a multitude (several tens to several hundreds) of mutually orthogonal digital modulated waves in a certain signal section.

A conventional OFDM communication apparatus performs time-frequency conversion on a reception signal through an FFT circuit, carries out a complex multiplication of pilot symbols contained in the reception signal with known signals, and thereby obtains a frequency response estimation value of the propagation path. Then, the conventional OFDM communication apparatus carries out a complex multiplication of the

frequency response estimation value with information OFDM symbols, and thereby compensates for propagation path distortion. This reception signal compensated for propagation path distortion is subjected to demodulation and error correction by an error correction circuit to obtain an information symbol string, which is reception data.

When long information is transmitted by the conventional OFDM communication apparatus above as shown in FIG.1, propagation path response estimation pilot symbols (hatching area) are inserted at predetermined intervals in information OFDM symbols to follow variations in momentarily changing propagation path responses. That is, as shown in FIG.2, information OFDM symbols 1 to n are compensated using a propagation path estimation value obtained with pilot symbol A and information OFDM symbols n+1 to 2n are compensated using a propagation path estimation value obtained with pilot symbol B.

However, in the case where such long information is transmitted, there is a problem that it is necessary to frequently insert known signals such as pilot symbols in order to follow time-variations of the propagation path, which reduces the transmission efficiency.

Disclosure of Invention

It is an object of the present invention to provide an OFDM communication apparatus and propagation path

estimation method capable of adaptively following time-variations of the transmission path and improving reception characteristics without reducing the transmission efficiency even when there are great time-variations in propagation path responses.

An essence of the present invention consists in implementing excellent reception characteristics by adaptively estimating propagation path responses using a decision value of a reception signal, that is, using a decision value of a received information signal as a known signal without frequently inserting propagation path estimation pilot symbols or without reducing the transmission efficiency even when long information is transmitted.

Brief Description of Drawings

FIG.1 illustrates a symbol configuration used in a conventional propagation path estimation method;

FIG.2 is a diagram to explain the conventional propagation path estimation method;

FIG.3 is a block diagram showing a configuration of an OFDM communication apparatus according to Embodiment 1 of the present invention;

FIG.4 is a block diagram showing an internal configuration of a propagation path estimation/compensation circuit of the OFDM communication apparatus according to Embodiment 1 of the present invention;

FIG.5 is a block diagram showing an internal configuration of the propagation path estimation value update circuit shown in FIG.4;

FIG.6 illustrates a symbol configuration used in the propagation path estimation method according to the present invention;

FIG.7 is a diagram to explain the propagation path estimation method according to the present invention;

FIG.8 is a block diagram showing an internal configuration of a propagation path estimation value update circuit in a propagation path estimation/compensation circuit of the OFDM communication apparatus according to Embodiment 2 of the present invention;

FIG.9 is a block diagram showing an internal configuration of a propagation path estimation value update circuit in a propagation path estimation/compensation circuit of an OFDM communication apparatus according to Embodiment 3 of the present invention;

FIG.10 is a block diagram showing an internal configuration of a propagation path estimation value update circuit in a propagation path estimation/compensation circuit of an OFDM communication apparatus according to Embodiment 4 of the present invention;

FIG.11 is a block diagram showing an internal configuration of the propagation path estimation value

update circuit in the propagation path estimation/compensation circuit of the OFDM communication apparatus according to Embodiment 4 of the present invention;

FIG.12 is a block diagram showing an internal configuration of a propagation path estimation/compensation circuit of an OFDM communication apparatus according to Embodiment 5 of the present invention;

FIG.13 is a block diagram showing an internal configuration of a propagation path estimation value update circuit in the propagation path estimation/compensation circuit of the OFDM communication apparatus according to Embodiment 5 of the present invention;

FIG.14 is a block diagram showing an internal configuration of a propagation path estimation value update circuit in a propagation path estimation/compensation circuit of an OFDM communication apparatus according to Embodiment 6 of the present invention;

FIG.15 is a block diagram showing an internal configuration of a propagation path estimation value update circuit in a propagation path estimation/compensation circuit of an OFDM communication apparatus according to Embodiment 7 of the present invention; and

FIG.16 is a block diagram showing an internal

configuration of the propagation path estimation value update circuit in the propagation path estimation/compensation circuit of the OFDM communication apparatus according to Embodiment 7 of the present invention.

Best Mode for Carrying out the Invention

With reference now to the attached drawings, embodiments of the present invention will be explained in detail below.

(Embodiment 1)

FIG.3 is a block diagram showing a configuration of an OFDM communication apparatus according to Embodiment 1 of the present invention. A signal used in OFDM communication has a configuration as shown in FIG.6. That is, the signal is configured by a preamble other than pilot symbol followed by a propagation path response estimation pilot symbol, which is a known signal, and information OFDM symbols. Thus, a propagation path estimation pilot symbol is added only at the beginning of the information symbols to be transmitted.

An OFDM signal received via antenna 101 is subjected to normal radio reception processing by radio reception circuit 102 and becomes a baseband signal. This baseband signal is subjected to quasi-coherent detection processing by a coherent detector, stripped of an

unnecessary frequency component by a low-pass filter and A/D-converted. As a result of coherent detection processing, the reception signal is divided into an in-phase component and quadrature component, but these are only expressed as one signal route in the drawing.

This baseband signal is subjected to an FFT (Fast Fourier Transform) calculation by FFT circuit 103 and transformed to signals assigned to different subcarriers. The signal subjected to the FFT calculation by FFT section 103 is sent to propagation path estimation/compensation circuit 104, which carries out a complex multiplication of a pilot symbol with a known signal included in the reception OFDM signal, thereby carries out a propagation path estimation and obtains a first propagation path estimation value (initial value).

Propagation path estimation/compensation circuit 104 successively performs propagation path distortion compensation of information OFDM symbols using the first propagation path estimation value for every OFDM symbol. The information symbols compensated for propagation path distortion are successively sent to error correction circuit 105 where errors are corrected. Error correction circuit 105 outputs an information symbol string, which has been subjected to error correction in units of transmission path coding. This information symbol string is sent to error detection circuit 106 where the information symbol string is subjected to error detection and output as reception data.

The information symbol string compensated for propagation path distortion is sent to hard decision circuit 107. Hard decision circuit 107 performs hard decision processing on the information symbols compensated for propagation path distortion. That is, signal points of information symbols during transmission are subjected to a hard decision. The information symbol string subjected to this hard decision is sent to propagation path estimation/compensation circuit 104. Propagation path estimation/compensation circuit 104 uses these hard decision information symbols as known signals, carries out a complex multiplication with FFT-calculated signals and thereby carries out a propagation path estimation and obtains a propagation path estimation value. This propagation path estimation value is updated to a first propagation path estimation value.

This new propagation path estimation value is subjected to a complex multiplication with information OFDM symbols and thereby propagation path distortion compensation is carried out. The reception signal compensated for propagation path distortion is sent to error correction circuit 105 where errors are corrected. The information symbol string output from error correction circuit 105 is sent to error detection circuit 106 where the information symbol string is subjected to error detection and output as reception data.

By the way, a propagation path estimation value can

be updated for every information symbol or for every plurality of information symbols. When a propagation path estimation value is updated for every plurality of information symbols, it is possible to provide a switch, etc. after error correction circuit 105 to switch between the output to hard decision circuit 107 and the output to detection circuit 106 through a control signal.

On the other hand, an information signal, which is transmission data for every subcarrier, is subjected to digital modulation processing with QPSK (Quadrature Phase Shift Keying) or QAM (Quadrature Amplitude Modulation), etc. by a modulation section, which is not shown in the drawing, and then subjected to an IFFT (Inverse Fast Fourier Transform) calculation by IFFT circuit 108 and becomes an OFDM signal. This OFDM signal is D/A-converted and then sent to radio transmission circuit 109 where the OFDM signal is subjected to radio transmission processing and then transmitted as a transmission signal via antenna 101.

Then, the operation of the OFDM communication apparatus in the above configuration will be explained.

The OFDM signal received via antenna 101 is subjected to normal radio reception processing by radio reception circuit 102, becomes a baseband signal and is subjected to an FFT calculation by FFT circuit 103 and transformed to signals assigned to different subcarriers.

This signal is sent to propagation path estimation/compensation circuit 104. As shown in FIG.4,

propagation path estimation/compensation circuit 104 includes register 201 that stores the output from FFT circuit 103, multiplier 203 that carries out a complex multiplication of this FFT output with a known signal or the output from hard decision circuit 107, propagation path estimation value update circuit 204 that stores a propagation path estimation value, which is the output from multiplier 203, and updates to a new propagation path estimation value and multiplier 202 that carries out a complex multiplication of the propagation path estimation value with FFT output.

Propagation path estimation/compensation circuit 104 also includes switch 205 to switch between multiplier 203 and multiplier 202 to which the FFT output is output, switch 206 to switch between the output from FFT circuit 103 and the FFT output stored in register 201 to be output to multiplier 203 and switch 207 to switch between a known signal or the output from hard decision circuit 107 to be output to multiplier 203.

Furthermore, propagation path estimation value update circuit 204 has register 301 as shown in FIG.5.

First, propagation path estimation/compensation is performed using a pilot symbol. A signal sent to propagation path estimation/compensation circuit 104, that is, FFT output is sent to multiplier 203 first and multiplier 203 carries out a complex multiplication of a pilot symbol of the FFT output with a known signal. Thus, a first propagation path estimation value (initial

value) is obtained. At this time, switches 205 to 207 are set so that the FFT output and known signal are input to multiplier 203. This propagation path estimation value is stored in register 301 of propagation path estimation value update circuit 204.

On the other hand, this propagation estimation value is sent to multiplier 202 and multiplier 202 multiplies the propagation estimation value by information symbols of the FFT output. In this way, the information symbols are compensated for propagation path distortion. The information symbols compensated for propagation path distortion in this way are sent to error correction circuit 105.

The information symbols compensated for propagation path distortion are sent to error correction circuit 105, subjected there to error correction and then sent to error detection circuit 106 where the information symbols are subjected to error detection and output as reception data.

Furthermore, the information symbols compensated for propagation path distortion are sent to hard decision circuit 107 where signal points of the information symbols during transmission are decided and the result of this signal point decision is sent to propagation path estimation/compensation circuit 104. That is, the information symbols subjected to a hard decision in this way are sent to multiplier 203 of on propagation path estimation/compensation circuit 104. Then, propagation

path estimation/compensation is performed using this information symbols subjected to a hard decision. Propagation path estimation/compensation circuit 104 uses these hard decision information symbols instead of a known signal and carries out a complex multiplication of these hard decision information symbols with the FFT output. At this time, the FFT output is stored in register 201. In this case, switches 205 to 207 are set so that the FFT output stored in register 201 and the hard decision output are output to multiplier 203.

In this way, a propagation path estimation value is obtained through a complex multiplication of the hard decision information symbols with FFT output. This propagation path estimation value is sent to propagation path estimation value update circuit 204. Then, the propagation path estimation value (initial value) stored in register 301 of propagation path estimation value update circuit 204 is updated using this propagation path estimation value.

Moreover, the updated propagation path estimation value is sent to multiplier 202 and multiplier 202 multiplies the updated propagation path estimation value by the information symbols of the FFT output. In this way, the information symbols are compensated for propagation path distortion. The information symbols compensated for propagation path distortion in this way are sent to error correction circuit 105.

The information symbols compensated for propagation

path distortion are sent to error correction circuit 105 and subjected to error correction and then sent to error detection circuit 106, subjected there to error correction and output as reception data.

In such a propagation path estimation method, as shown in FIG.7, information symbols 1 to n are compensated for propagation path distortion using a propagation path estimation value (X) obtained with a pilot symbol (hatching area) and information symbols n+1 to 2n are compensated for propagation path distortion using a propagation path estimation value (Y) obtained by using the hard decision outputs of information symbols 1 to n as known signals and information symbols 2n+1 to 3n are compensated for propagation path distortion using the propagation path estimation value (Y) obtained by using the hard decision outputs of information symbols n+1 to 2n as known signals. Therefore, even when long information is sent, it is possible to estimate propagation path responses without inserting pilot symbols between information OFDM symbols consecutively transmitted, thus achieving excellent reception characteristics without reducing the transmission efficiency.

Furthermore, when the hard decision output of an information symbol is used as a known signal, it is also possible to obtain quality information about a plurality of information symbols, input the quality information to propagation path estimation value update circuit 204

and decide which information symbol hard decision output is appropriate as a known signal for calculation of a propagation path estimation value. This makes it possible to obtain an optimal propagation path estimation value and carry out appropriate propagation path distortion compensation for information symbols. Therefore, even when long information is sent or when there is a large time-variation in propagation path responses, it is possible to adaptively follow time-variations of the transmission path and maintain a low error rate without reducing the transmission efficiency.

(Embodiment 2)

The OFDM communication apparatus according to this embodiment updates a propagation path estimation value through propagation path estimation value update circuit 204 using both propagation path estimation values obtained using information symbols after a hard decision and past propagation path estimation values.

Since the configuration of the OFDM communication apparatus according to this embodiment is the same as that of Embodiment 1 except the propagation path estimation value update circuit, the propagation path estimation value update circuit will be explained.

FIG.8 is a block diagram showing an internal configuration of the propagation path estimation value update circuit in the propagation path

estimation/compensation circuit of the OFDM communication apparatus according to Embodiment 2 of the present invention. This propagation path estimation value update circuit includes register 601 that stores propagation path estimation values and outputs these propagation path estimation values to multiplier 202, multipliers 603 and 604 that multiply the propagation path estimation values stored in register 601 by weighting factors, adder 605 that adds up the multiplication results of multipliers 603 and 604 and per-subcarrier factor selection section 602 that selects weighting factors of the output of multiplier 203 and past propagation path estimation values stored in register 601 using a control signal.

The propagation path estimation value update circuit shown in FIG.8 updates a propagation path estimation value using both propagation path estimation values obtained using information symbols after a hard decision and past propagation path estimation values and the propagation path estimation value to be updated follows expression (1), for example.

(Estimation value to be updated) = W×(output of multiplier 203) + (1-W)×(immediately preceding estimation value) ··· Expression (1)

where, W denotes a weighting factor and is given by per-subcarrier factor selection section 602. Per-subcarrier factor selection section 602 provides a weighting factor for every subcarrier based on past

propagation path response estimation values. Per-subcarrier factor selection section 602 selects preset weighting factors according to a control signal based on information such as channel quality. By the way, a same weighting factor can also be used in all cases.

More specifically, propagation path estimation value update circuit 204 outputs a past (here, immediately preceding) propagation path estimation value from register 601 to multiplier 604. On the other hand, a propagation path estimation value (output of multiplier 203) obtained using the current information symbol after a hard decision as a known signal is output to multiplier 603.

According to a control signal based on information such as channel quality, per-subcarrier factor selection section 602 selects a weighting factor (W) to be multiplied on the current propagation path estimation value and past propagation path estimation value and outputs the weighting factor for the current propagation path estimation value to multiplier 603 and the weighting factor for the past propagation path estimation value to multiplier 604.

Multipliers 603 and 604 each assign weights to the current propagation path estimation value and past propagation path estimation value, and output these results to adder 605. Adder 605 adds up the respective weighted propagation path estimation values and calculates a propagation path estimation value to be

updated. Then, the calculated propagation path estimation values are sent to register 601 and the propagation path estimation values stored in the register are updated.

According to this embodiment, new propagation path estimation values are obtained using also past propagation path response estimation values, and therefore it is possible to obtain high estimation accuracy using these propagation path estimation values and carry out propagation path distortion compensation for information symbols more accurately.

(Embodiment 3)

The OFDM communication apparatus according to this embodiment adds processing of averaging propagation path estimation values corresponding to n symbols using information symbols after a hard decision.

Since the configuration of the OFDM communication apparatus according to this embodiment is the same as that of Embodiment 1 except the propagation path estimation value update circuit, the propagation path estimation value update circuit will be explained.

FIG.9 is a block diagram showing an internal configuration of the propagation path estimation value update circuit in the propagation path estimation/compensation circuit of the OFDM communication apparatus according to Embodiment 3 of the present invention. This propagation path estimation

value update circuit includes register 701 that stores propagation path estimation values and outputs these propagation path estimation values to multiplier 202 and averaging section 702 that averages propagation path estimation values obtained using information symbols after a hard decision for n symbols. Furthermore, the propagation path estimation value update circuit also includes switch 703 that selects whether the propagation path estimation value (output of multiplier 203) is directly output to register 701 or output to averaging section 702.

In this configuration, in the case where a propagation path estimation value is obtained using a pilot symbol, switch 703 is set so that the output of multiplier 203 is sent to register 701 and the propagation path estimation value is sent to register 701 and stored in register 701. On the other hand, in the case where a propagation path estimation value is obtained using information symbols after a hard decision, switch 703 is set so that the output of multiplier 203 is sent to averaging section 702, the propagation path estimation values are sent to averaging section 702 where propagation path estimation values corresponding to n symbols are averaged. The averaged propagation path estimation value is sent to register 701 and the propagation path estimation value stored in register 701 is updated. In the case where the amplitude of a transmission signal contains information such as multi-value QAM, averaging

section 702 can also be configured so as not to include values of signal points having a small amplitude in averaging and thereby further reduce deterioration by additive noise.

This embodiment averages newly obtained propagation path estimation values for a plurality of symbols, and therefore can reduce estimation errors due to additive noise. Using these propagation path estimation values makes it possible to achieve higher estimation accuracy and carry out a propagation path distortion compensation for information symbols more accurately.

(Embodiment 4)

The OFDM communication apparatus according to this embodiment adds processing of averaging propagation path estimation values for n symbols through propagation path estimation value update circuit 204 by using information symbols after a hard decision and updates propagation path estimation values using both averaged propagation path estimation values and past propagation path estimation values.

Since the configuration of the OFDM communication apparatus according to this embodiment is the same as that of Embodiment 1 except the propagation path estimation value update circuit, the propagation path estimation value update circuit will be explained.

FIG.10 is a block diagram showing an internal configuration of the propagation path estimation value

update circuit in the propagation path estimation/compensation circuit of the OFDM communication apparatus according to Embodiment 4 of the present invention. This propagation path estimation value update circuit includes register 801 that stores propagation path estimation values and outputs these propagation path estimation values to multiplier 202, multipliers 803 and 804 that multiply the propagation path estimation values stored in register 801 by weighting factors, adder 805 that adds up the multiplication results of multipliers 803 and 804, per-subcarrier factor selection section 802 that selects weighting factors of the output of multiplier 203 and past propagation path estimation values stored in register 801 using a control signal and averaging section 806 that averages propagation path estimation values obtained using information symbols after a hard decision for n symbols. Furthermore, the propagation path estimation value update circuit also includes switch 807 that selects whether the propagation path estimation value (output of multiplier 203) is directly output to register 803 or output to averaging section 806 and then output to multiplier 803.

The propagation path estimation value update circuit shown in FIG.10 averages propagation path estimation values obtained using information symbols after a hard decision for n symbols and updates a propagation path estimation value using both the averaged

propagation path estimation values and past propagation path estimation values and the propagation path estimation value to be updated follows expression (2), for example.

(Estimation value to be updated) = W×(output of averaging circuit) + (1-W)×(immediately preceding estimation value) ··· Expression (2)

where, W denotes a weighting factor and is given by per-subcarrier factor selection section 802. Per-subcarrier factor selection section 802 provides a weighting factor for every subcarrier based on past propagation path response estimation values. Per-subcarrier factor selection section 802 selects preset weighting factors according to a control signal based on information such as channel quality. By the way, a same weighting factor can also be used in all cases.

More specifically, propagation path estimation value update circuit 204 outputs a past (here, immediately preceding) propagation path estimation value from register 801 to multiplier 804.

On the other hand, in the case where a propagation path estimation value is obtained using a pilot symbol, switch 807 is set so that the output of multiplier 203 is sent to multiplier 803 and the propagation path estimation value is sent to multiplier 803 and a weighting factor is multiplied by multiplier 803. On the other hand, in the case where a propagation path estimation value is obtained using information symbols after a hard

decision, switch 807 is set so that the output of multiplier 203 is sent to averaging section 806, the propagation path estimation values are sent to averaging section 806 where propagation path estimation values corresponding to n symbols are averaged. The averaged propagation path estimation value is sent to multiplier 803 and a weighting factor is multiplied by multiplier 803.

At this time, according to a control signal based on information such as channel quality, per-subcarrier factor selection section 802 selects weighting factors (W) to be multiplied on the current propagation path estimation value and past propagation path estimation values and outputs the weighting factor for the average output of the current propagation path estimation value to multiplier 803 and weighting factor for the past propagation path estimation value to multiplier 804.

Multipliers 803 and 804 assign weights to the average output of the current propagation path estimation values and past propagation path estimation values, respectively, and output these results to adder 805. Adder 805 adds up the respective weighted propagation path estimation values and calculates a propagation path estimation value to be updated. Then, the calculated propagation path estimation value is sent to register 801 and the propagation path estimation values stored in the register are updated. In the case where the amplitude of a transmission signal contains information such as multi-value QAM, averaging section 806 can be configured

so as not to include values of signal points having a small amplitude in averaging and thereby further reduce deterioration by additive noise.

This embodiment averages newly obtained propagation path estimation values for a plurality of symbols, and thereby can reduce estimation errors due to additive noise. Moreover, new propagation path estimation values are obtained also using past propagation path response estimation values, and therefore it is possible to obtain higher estimation accuracy. As a result, it is possible to carry out propagation path distortion compensation for information symbols more accurately.

In this embodiment, it is also possible to enter a CRC (Cyclic Redundancy Check) result to per-subcarrier factor selection section 802 as external quality information as shown in FIG.11. This is intended to set so that averaged blocks including information symbols in which errors have been detected as a result of the CRC are not used as the averaging output. At this time, weighting factor W in expression (2) above becomes 0.

Thus, applying external quality information to selection of weighting factors makes it possible to reduce estimation errors due to bit errors and achieve drastic improvement in the estimation accuracy.

(Embodiment 5)

The OFDM communication apparatus according to this embodiment uses signals compensated for propagation path

distortion as information OFDM symbols stored to be used for successive propagation path estimations. More specifically, the OFDM communication apparatus according to this embodiment calculates a difference between an information OFDM symbol compensated for propagation path distortion stored in a register and a hard decision output and updates the past propagation path estimation value by an amount corresponding to the difference.

Since the configuration of the OFDM communication apparatus according to this embodiment is the same as that of Embodiment 1 except the propagation path estimation/compensation circuit, the propagation path estimation/compensation circuit will be explained.

FIG.12 is a block diagram showing an internal configuration of the propagation path estimation/compensation circuit of the OFDM communication apparatus according to Embodiment 5 of the present invention.

The propagation path estimation/compensation circuit 104 includes multiplier 1001 that carries out a complex multiplication of the output from FFT circuit 103 (FFT output) with a known signal, propagation path estimation value update circuit 1002 that stores the output of multiplier 1001, that is, a propagation path estimation value and updates the propagation path estimation value to a new propagation path estimation value, multiplier 1003 that carries out a complex multiplication of the output from propagation path

estimation value update section 1002 with the FFT output, register 1004 that stores information symbols compensated for propagation path distortion, which is the output of multiplier 1003 and subtractors 1005 and 1006 that calculates a difference between the information symbol after propagation path distortion compensation and the output of hard decision circuit 107. Moreover, propagation path estimation/compensation circuit 104 also includes switches 1007 and 1008 to select multiplier 1003 or multiplier 1001 to which the FFT output is output. Here, the FFT output, known signal and hard decision output are expressed with I components and Q components.

As shown in FIG.13, this propagation path estimation value update circuit 1002 includes registers 1101 and 1102 that store a propagation path estimation value (output of multiplier 1001) and output the propagation path estimation value to adders 1103 and 1104, multipliers 1105 and 1106 that multiply the outputs of subtractors 1005 and 1006 by weighting factors, adders 1103 and 1104 that add up the multiplication results of multipliers 1105 and 1106 and the propagation path estimation values stored in registers 1101 and 1102. Moreover, propagation path estimation value update circuit 1002 also includes switches 1107 and 1108 to select registers 1101, 1102 or adders 1103 and 1104 to which the output of multiplier 1001 is output.

The operation of the OFDM communication apparatus in the above configuration will be explained. The signal

sent to propagation path estimation/compensation circuit 104, that is, FFT output, is sent to multiplier 1001 first and multiplier 1001 carries out a complex multiplication of the I component and Q component of the FFT output with the I component and Q component of a known signal. In this way, a propagation path estimation value is obtained. At this time, switches 1007 and 1008 are set so that the FFT output and known signal are input to multiplier 1001. This propagation path estimation value is stored in registers 1101 and 1102 of propagation path estimation value update circuit 1002. At this time, switches 1107 and 1108 of propagation path estimation value update circuit 1002 are set so that the output of multiplier 1001 is sent to registers 1101 and 1102.

Moreover, this propagation path estimation value is sent to multiplier 1003 and multiplier 1003 carries out a complex multiplication of the I component and Q component of the FFT output with the I component and Q component of the information symbol. In this way, the information symbol is compensated for propagation path distortion. The information symbol compensated for propagation path distortion in this way is sent to error correction circuit 105. Furthermore, the information symbol compensated for propagation path distortion is stored in register 1004.

The information symbol compensated for propagation path distortion is sent to error correction circuit 105, subjected there to error correction and then sent to error

detection circuit 106, subjected there to error detection and output as reception data.

Furthermore, the information symbols compensated for propagation path distortion are sent to hard decision circuit 107 where signal points of the information symbols during transmission are decided and the result of this signal point decision is sent to propagation path estimation/compensation circuit 104. That is, the I component of the hard-decided information symbol string is sent to subtractor 1005 of propagation path estimation/compensation circuit 104 and the Q component is sent to subtractor 1006 of propagation path estimation/compensation circuit 104.

Subtractor 1005 calculates a difference between the I component of the hard-decided information symbol string and the I component of the information symbol compensated for propagation path distortion stored in the register and this difference value is input to multiplier 1105 of propagation path estimation value update circuit 1002.

Subtractor 1006 calculates a difference between the Q component of the hard-decided information symbol string and the Q component of the information symbol compensated for propagation path distortion stored in the register and this difference value is input to multiplier 1106 of propagation path estimation value update circuit 1002.

Multipliers 1105 and 1106 multiply the difference values by weighting factors ($0<W\leqq 1$). Thus, multiplying by weighting factor W reduces the difference values,

preventing influences by large estimation errors. This weighting coefficient W can be fixed or changed according to the channel condition as appropriate.

The difference values with weighting factor W multiplied are sent to adders 1103 and 1104. Adder 1103 adds up the I components of the difference values and the I components of the propagation path estimation values (output of multiplier 1001) and adder 1104 adds up the Q components of the difference values and the Q components of the propagation path estimation values (output of multiplier 1001) to produce a new propagation path estimation value. This new propagation path estimation value is sent to registers 1101 and 1102, updated and sent to multiplier 1003 of propagation path estimation/compensation circuit 104.

Multiplier 1003 carries out a complex multiplication of the I component and Q component of the information symbol of the FFT output with the I component and Q component of the propagation path estimation value. In this way, the information symbol is compensated for propagation path distortion. The information symbol compensated for propagation path distortion in this way is sent to error correction circuit 105.

The information symbol compensated for propagation path distortion is sent to error correction circuit 105, subjected there to error correction and then sent to error detection circuit 106, subjected there to error detection and output as reception data.

As shown above, this embodiment allows propagation path responses to be estimated without inserting pilot symbols between information OFDM symbols consecutively transmitted, making it possible to obtain excellent reception characteristics without reducing the transmission efficiency. Moreover, even if there is a residual phase error, this embodiment only corrects the difference while compensating the residual phase error, and therefore can reduce deterioration of the estimation accuracy due to the residual phase error.

(Embodiment 6)

The OFDM communication apparatus according to this embodiment includes propagation path estimation value update circuit 1002 that adopts variable weighting factors using past propagation path estimation values as quality information.

Since the configuration of the OFDM communication apparatus according to this embodiment is the same as that of Embodiment 5 except the propagation path estimation value update circuit, the propagation path estimation value update circuit will be explained.

FIG.14 is a block diagram showing an internal configuration of the propagation path estimation value update circuit of the OFDM communication apparatus according to Embodiment 6 of the present invention.

This propagation path estimation value update circuit 1002 includes registers 1201 and 1202 that store

propagation path estimation values (output of multiplier 1001) and output these propagation path estimation values to adders 1204 and 1205, multipliers 1206 and 1207 that multiply the outputs of subtractors 1005 and 1006 by weighting factors, adders 1204 and 1205 that add up the multiplication results of multipliers 1206 and 1207 and propagation path estimation values stored in registers 1201 and 1202, per-subcarrier factor selection section 1203 that selects weighting factor Wk using the propagation path estimation values stored in registers 1201 and 1202 as quality information. Furthermore, propagation path estimation value update circuit 1002 also includes switches 1208 and 1209 to select registers 1201, 1202 or adders 1204 and 1205 to which the output of multiplier 1001 is output.

The operation of the OFDM communication apparatus in the above configuration will be explained. The propagation path estimation values (output of multiplier 1001) are stored in registers 1201 and 1202 of propagation path estimation value update circuit 1002. At this time, switches 1208 and 1209 of propagation path estimation value update circuit 1002 are set so that the output of multiplier 1001 is sent to registers 1201 and 1202.

Difference values from subtractors 1005 and 1006 are input to multipliers 1206 and 1207. Multipliers 1206 and 1207 multiply the difference values by weighting factor Wk. This weighting factor Wk is selected by per-subcarrier factor selection section 1203.

Weighting factor Wk is selected using the propagation path estimation values stored in registers 1201 and 1202 as quality information. Thus, difference values are reduced by multiplying the difference values by weighting factor Wk, and therefore it is possible to prevent influences by large estimation errors.

The difference values with weighting factor Wk multiplied are sent to adders 1204 and 1205. Then, adder 1204 adds up the I components of the difference values and the I components of the propagation path estimation values (output of multiplier 1001) and adder 1205 adds up the Q components of the difference values and the Q components of the propagation path estimation values (output of multiplier 1001) to produce a new propagation path estimation value. This new propagation path estimation value is sent to registers 1201 and 1202, updated and sent to multiplier 1003 of propagation path estimation/compensation circuit 104.

This embodiment allows propagation path responses to be estimated without inserting pilot symbols between information OFDM symbols consecutively transmitted and changes weighting factors for every subcarrier, making it possible to obtain excellent reception characteristics without reducing the transmission efficiency. Moreover, even if there is a residual phase error, this embodiment only corrects the difference while compensating the residual phase error, and therefore can reduce deterioration of the estimation accuracy due to the

residual phase error.

(Embodiment 7)

The OFDM communication apparatus according to this embodiment includes propagation path estimation value update circuit 1002 that averages the outputs of the subtractors.

Since the configuration of the OFDM communication apparatus according to this embodiment is the same as that of Embodiment 6 except the propagation path estimation value update circuit, the propagation path estimation value update circuit will be explained.

FIG.15 is a block diagram showing an internal configuration of the propagation path estimation value update circuit in the propagation path estimation/compensation circuit of the OFDM communication apparatus according to Embodiment 7 of the present invention.

In propagation path estimation value update circuit 1002, the I component of the difference value of subtractor 1005 is input to averaging section 1301 and the Q component of the difference value of subtractor 1006 is input to averaging section 1302. Averaging sections 1301 and 1302 perform averaging processing on difference values corresponding to n symbols. The I component of this averaged difference value is sent to multiplier 1206 and the Q component of this averaged difference value is sent to multiplier 1207. The processing hereafter is the same

as that of Embodiment 6. Furthermore, in the case where the amplitude of a transmission signal contains information such as multi-value QAM, averaging sections 1301 and 1302 can be configured so as not to include values of signal points having a small amplitude in averaging and thereby further reduce deterioration by additive noise.

This embodiment can obtain a propagation path variation estimation value more reliably by averaging the outputs of the subtractors, thus obtaining excellent reception characteristics without reducing the transmission efficiency. Moreover, even if there is a residual phase error, this embodiment only corrects the difference while compensating the residual phase error, and therefore can reduce deterioration of the estimation accuracy due to the residual phase error.

In this embodiment, it is also possible to enter a CRC (Cyclic Redundancy Check) result to per-subcarrier factor selection section 1203 as external quality information as shown in FIG.16. This is intended to set so that averaged blocks in which errors have been detected as a result of the CRC are not used as the difference value of the estimated propagation path variation.

Thus, applying external quality information to selection of weighting factors makes it possible not only to obtain a propagation path variation estimation value more accurately but also to reduce estimation errors due to bit errors, thereby obtaining excellent reception

characteristics without reducing the transmission efficiency. Moreover, even if there is a residual phase error, this embodiment only corrects the difference while compensating the residual phase error, and therefore can reduce deterioration of the estimation accuracy due to the residual phase error.

The present invention is not limited to Embodiments 1 to 7, but can be implemented with various modifications. For example, the present invention can be implemented by combining Embodiments 1 to 7 as appropriate.

The OFDM communication apparatus of the present invention adopts a configuration including an estimation value calculation section that obtains a propagation path estimation value using a known signal of an OFDM signal containing the known signal, a propagation path distortion compensation section that compensates propagation path distortion for the information signal obtained from the OFDM signal using the propagation path estimation value and a hard decision section that decides transmission signal points using the information signal compensated for propagation path distortion, wherein the estimation value calculation section calculates a propagation path estimation value using the hard-decided signal instead of the known signal.

This configuration calculates a propagation path estimation value using a hard-decided information signal instead of a known signal, making it possible to estimate propagation path responses without inserting pilot

symbols between information OFDM symbols consecutively transmitted even when long information is sent and obtain excellent reception characteristics without reducing the transmission efficiency.

The OFDM communication apparatus adopts a configuration including an estimation value calculation section that obtains a propagation path estimation value using a known signal of an OFDM signal containing the known signal, a propagation path distortion compensation section that compensates propagation path distortion for the information signal obtained from the OFDM signal using the propagation path estimation value and a hard decision section that decides transmission signal points using the information signal compensated for propagation path distortion, wherein the estimation value calculation section calculates a propagation path estimation value using a difference between the hard-decided signal and the information signal compensated for propagation path distortion.

This configuration can estimate propagation path responses without inserting pilot symbols between information OFDM symbols consecutively transmitted and obtain excellent reception characteristics without reducing the transmission efficiency. Moreover, even if there is a residual phase error, this embodiment only corrects the difference while compensating the residual phase error, and therefore can reduce deterioration of the estimation accuracy due to the residual phase error.

The OFDM communication apparatus in the above configuration has the propagation path estimation value calculation section that calculates a new propagation path estimation value using the propagation path estimation value obtained from the hard-decided current information signal and past information signal.

The OFDM communication apparatus in the above configuration includes weighting means for assigning weights to the hard-decided current information signal and past information signal.

These configurations obtain a new propagation path estimation value also using a past propagation path estimation value, and therefore can achieve high estimation accuracy by using this propagation path estimation value and carry out propagation path distortion compensation for information symbols more accurately.

The OFDM communication apparatus in the above configuration has the weighting section that assigns weights based on external quality information. This configuration applies the external quality information to selection of weighting factors, and therefore can reduce estimation errors due to bit errors and drastically improve the estimation accuracy.

The OFDM communication apparatus in the above configuration has the estimation value calculation section including an averaging section that averages information signals of a plurality of hard-decided

symbols.

This configuration averages newly obtained propagation path estimation values corresponding to a plurality of symbols, and therefore can reduce estimation errors due to additive noise and achieve high estimation accuracy and carry out propagation path compensation for information symbols more accurately by using this propagation path estimation value.

The communication apparatus of the present invention is characterized by comprising the OFDM communication apparatus in the above configuration. Furthermore, the base station apparatus of the present invention is characterized by comprising the OFDM communication apparatus in the above configuration.

These configurations can implement a radio communication system capable of estimating propagation path responses without inserting pilot symbols between information OFDM symbols consecutively transmitted even when long information is sent and obtaining excellent reception characteristics without reducing the transmission efficiency.

The propagation path estimation method of the present invention includes an estimation value calculating step of obtaining a propagation path estimation value using a known signal of an OFDM signal containing the known signal, a propagation path distortion compensating step of compensating propagation path distortion for the information signal obtained from

the OFDM signal using the propagation path estimation value and a hard decision step of deciding transmission signal points using the information signal compensated for propagation path distortion, wherein the estimation value calculating step calculates a propagation path estimation value using the hard-decided signal instead of the known signal.

This method calculates a propagation path estimation value using a hard-decided information signal instead of a known signal, making it possible to estimate propagation path responses without inserting pilot symbols between information OFDM symbols consecutively transmitted even when long information is sent and obtain excellent reception characteristics without reducing the transmission efficiency.

The propagation path estimation method of the present invention includes an estimation value calculating step of obtaining a propagation path estimation value using a known signal of an OFDM signal containing the known signal, a propagation path distortion compensating step of compensating propagation path distortion for the information signal obtained from the OFDM signal using the propagation path estimation value and a hard decision step of deciding transmission signal points using the information signal compensated for propagation path distortion, wherein the estimation value calculating step calculates a propagation path estimation value using a difference between the

hard-decided signal and the information signal compensated for propagation path distortion.

This method can estimate propagation path responses without inserting pilot symbols between information OFDM symbols consecutively transmitted, and therefore obtain excellent reception characteristics without reducing the transmission efficiency. Moreover, even if there is a residual phase error, this embodiment only corrects the difference while compensating the residual phase error, and therefore can reduce deterioration of the estimation accuracy due to the residual phase error.

As described above, the OFDM communication apparatus of the present invention adaptively estimates propagation path responses using a hard-decided signal, that is, using a decision value of the received information signal as a known signal, making it possible to maintain a low error rate by adaptively following time-variations of the transmission path even when long information is sent or when there is a great variation in propagation path responses.

This application is based on the Japanese Patent Application No.HEI 11-245299 filed on August 31, 1999, entire content of which is expressly incorporated by reference herein.

Industrial Applicability

The present invention is applicable to a base station

apparatus or communication terminal apparatus in a digital radio communication system.

What is claimed is:

1. An OFDM communication apparatus comprising:

estimation value calculating means for calculating a propagation path estimation value using a known signal of an OFDM signal containing said known signal;

propagation path distortion compensating means for compensating propagation path distortion for the information signal obtained from said OFDM signal using said propagation path estimation value; and

hard decision means for deciding transmission signal points using the information signal compensated for propagation path distortion, wherein said estimation value calculating means calculates a propagation path estimation value using said hard-decided signal instead of said known signal.

2. An OFDM communication apparatus comprising:

estimation value calculating means for calculating a propagation path estimation value using a known signal of an OFDM signal containing said known signal;

propagation path distortion compensating means for compensating propagation path distortion for the information signal obtained from said OFDM signal using said propagation path estimation value; and

hard decision means for deciding transmission signal points using the information signal compensated for propagation path distortion, wherein said estimation

value calculating means calculates a propagation path estimation value using a difference between said hard-decided signal and the information signal compensated for propagation path distortion.

3. The OFDM communication apparatus according to claim 1, wherein said estimation value calculating means calculates a new propagation path estimation value using the propagation path estimation value obtained from the hard-decided current information signal and hard-decided past information signal.

4. The OFDM communication apparatus according to claim 3, further comprising weighting means for assigning weights to the hard-decided current information signal and past information signal.

5. The OFDM communication apparatus according to claim 4, wherein said weighting means assigns weights based on external quality information.

6. The OFDM communication apparatus according to claim 1, wherein said estimation value calculating means comprises averaging means for averaging information signals of a plurality of hard-decided symbols.

7. A communication terminal apparatus equipped with an OFDM communication apparatus, said OFDM communication

apparatus comprising:

estimation value calculating means for calculating a propagation path estimation value using a known signal of an OFDM signal containing said known signal;

propagation path distortion compensating means for compensating propagation path distortion for the information signal obtained from said OFDM signal using said propagation path estimation value; and

hard decision means for deciding transmission signal points using the information signal compensated for propagation path distortion, wherein said estimation value calculating means calculates a propagation path estimation value using said hard-decided signal instead of said known signal.

8. A base station apparatus equipped with an OFDM communication apparatus, said OFDM communication apparatus comprising:

estimation value calculating means for calculating a propagation path estimation value using a known signal of an OFDM signal containing said known signal;

propagation path distortion compensating means for compensating propagation path distortion for the information signal obtained from said OFDM signal using said propagation path estimation value; and

hard decision means for deciding transmission signal points using the information signal compensated for propagation path distortion, wherein said estimation

value calculating means calculates a propagation path estimation value using said hard-decided signal instead of said known signal.

9. A propagation path estimation method comprising:

an estimation value calculating step of calculating a propagation path estimation value using a known signal of an OFDM signal containing said known signal;

a propagation path distortion compensating step of compensating propagation path distortion for the information signal obtained from said OFDM signal using said propagation path estimation value; and

a hard decision step of deciding transmission signal points using the information signal compensated for propagation path distortion, wherein said estimation value calculating step calculates a propagation path estimation value using said hard-decided signal instead of said known signal.

10. A propagation path estimation method comprising:

an estimation value calculating step of calculating a propagation path estimation value using a known signal of an OFDM signal containing said known signal;

a propagation path distortion compensating step of compensating propagation path distortion for the information signal obtained from said OFDM signal using said propagation path estimation value; and

a hard decision step of deciding transmission signal

points using the information signal compensated for propagation path distortion, wherein said estimation value calculating step calculates a propagation path estimation value using a difference between said hard-decided signal and the information signal compensated for propagation path distortion.

ABSTRACT

The baseband signal obtained from the reception signal is compensated for propagation path distortion using a propagation path estimation value obtained by propagation path estimation/compensation circuit 104. The information bit string compensated for propagation path distortion is periodically sent to hard-decision circuit 107 and subjected there to hard-decision processing. These information symbols subjected to a hard decision are sent to propagation path estimation/compensation circuit 104 where using these hard decision information symbols as known signals, a propagation path estimation is performed by carrying out a complex multiplication of the information symbols subjected to a hard decision with FFT-calculated signals and thereby a propagation path estimation value is obtained. This propagation path estimation value is updated to a first propagation path estimation value.

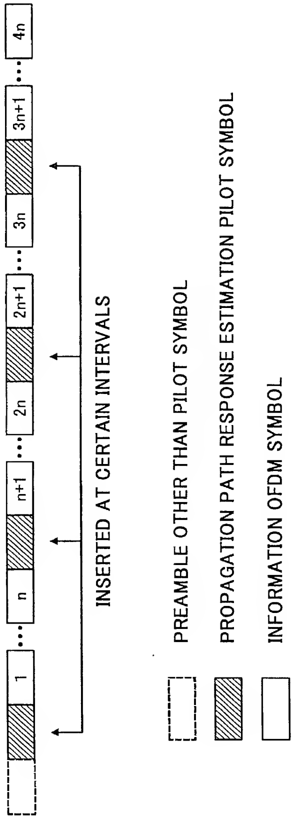

1
n
n+1
2n
2n+1
3n
3n+1
4n
INSERTED AT CERTAIN INTERVALS
PREAMBLE OTHER THAN PILOT SYMBOL
PROPAGATION PATH RESPONSE ESTIMATION PILOT SYMBOL
INFORMATION OFDM SYMBOL

FIG.1

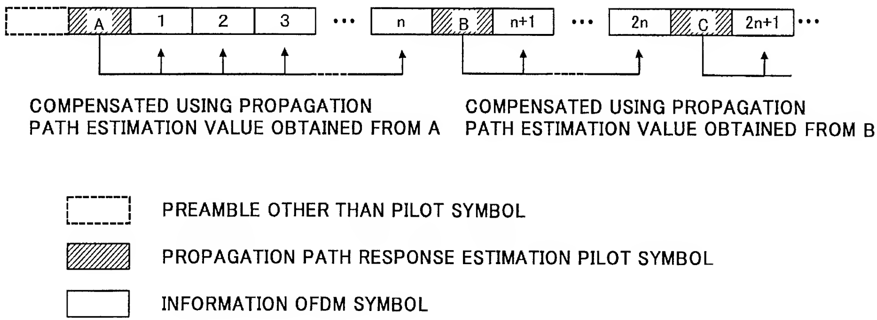

A
1
2
3
n
B
n+1
2n
C
2n+1
COMPENSATED USING PROPAGATION PATH ESTIMATION VALUE OBTAINED FROM A
COMPENSATED USING PROPAGATION PATH ESTIMATION VALUE OBTAINED FROM B
PREAMBLE OTHER THAN PILOT SYMBOL
PROPAGATION PATH RESPONSE ESTIMATION PILOT SYMBOL
INFORMATION OFDM SYMBOL

FIG.2

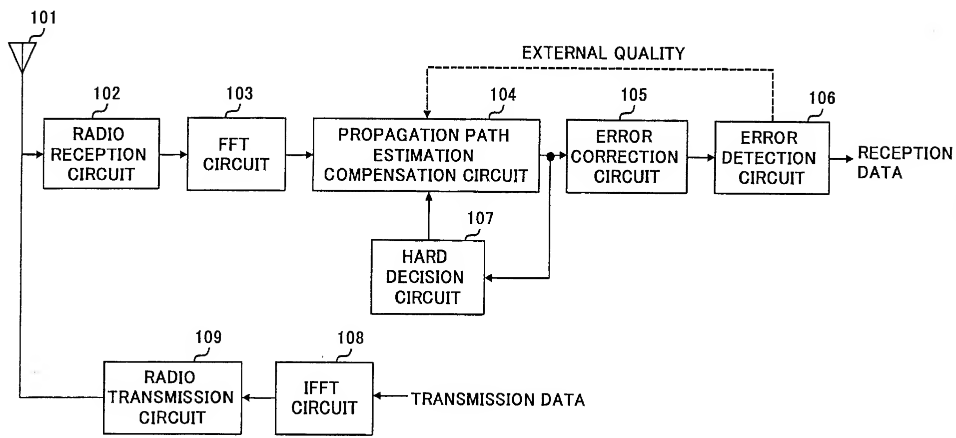

101
102
RADIO RECEPTION CIRCUIT
103
FFT CIRCUIT
104
PROPAGATION PATH ESTIMATION COMPENSATION CIRCUIT
105
ERROR CORRECTION CIRCUIT
106
ERROR DETECTION CIRCUIT
RECEPTION DATA
EXTERNAL QUALITY
107
HARD DECISION CIRCUIT
108
IFFT CIRCUIT
109
RADIO TRANSMISSION CIRCUIT
TRANSMISSION DATA

FIG.3

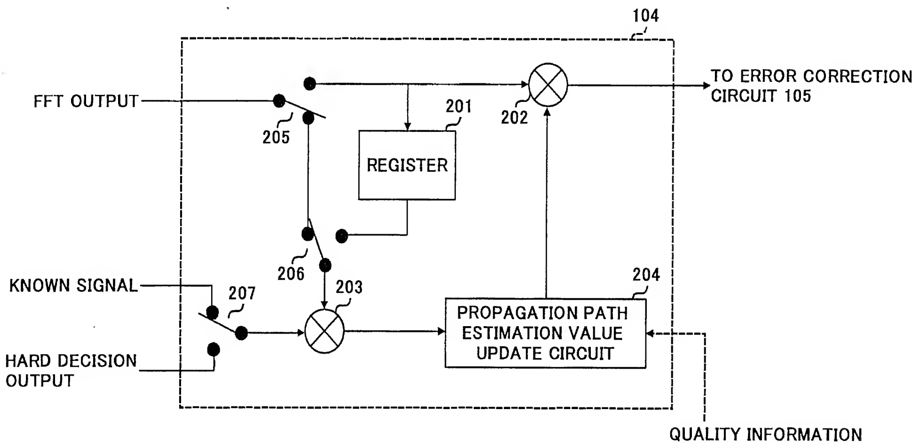

104
FFT OUTPUT
205
201
REGISTER
202
TO ERROR CORRECTION CIRCUIT 105
206
KNOWN SIGNAL
207
203
204
PROPAGATION PATH ESTIMATION VALUE UPDATE CIRCUIT
HARD DECISION OUTPUT
QUALITY INFORMATION

FIG.4

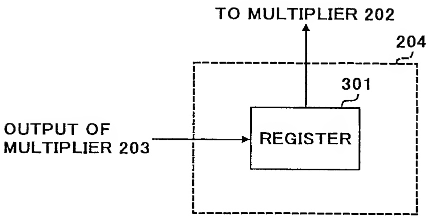
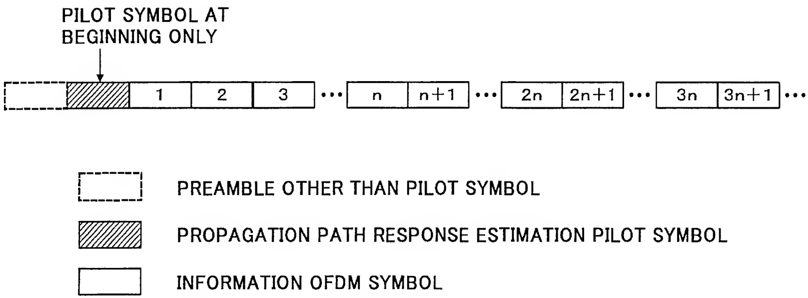
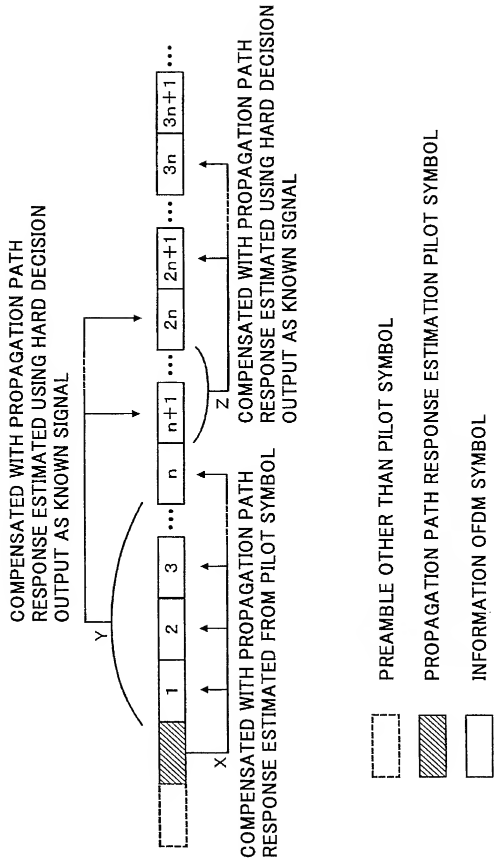

TO MULTIPLIER 202
204
301
OUTPUT OF
MULTIPLIER 203
REGISTER

FIG.5



PILOT SYMBOL AT BEGINNING ONLY
1
2
3
n
n+1
2n
2n+1
3n
3n+1
PREAMBLE OTHER THAN PILOT SYMBOL
PROPAGATION PATH RESPONSE ESTIMATION PILOT SYMBOL
INFORMATION OFDM SYMBOL

FIG.6



COMPENSATED WITH PROPAGATION PATH RESPONSE ESTIMATED USING HARD DECISION OUTPUT AS KNOWN SIGNAL
Y
1
2
3
n
n+1
2n
2n+1
3n
3n+1
X
Z
COMPENSATED WITH PROPAGATION PATH RESPONSE ESTIMATED FROM PILOT SYMBOL
COMPENSATED WITH PROPAGATION PATH RESPONSE ESTIMATED USING HARD DECISION OUTPUT AS KNOWN SIGNAL
PREAMBLE OTHER THAN PILOT SYMBOL
PROPAGATION PATH RESPONSE ESTIMATION PILOT SYMBOL
INFORMATION OFDM SYMBOL

FIG.7

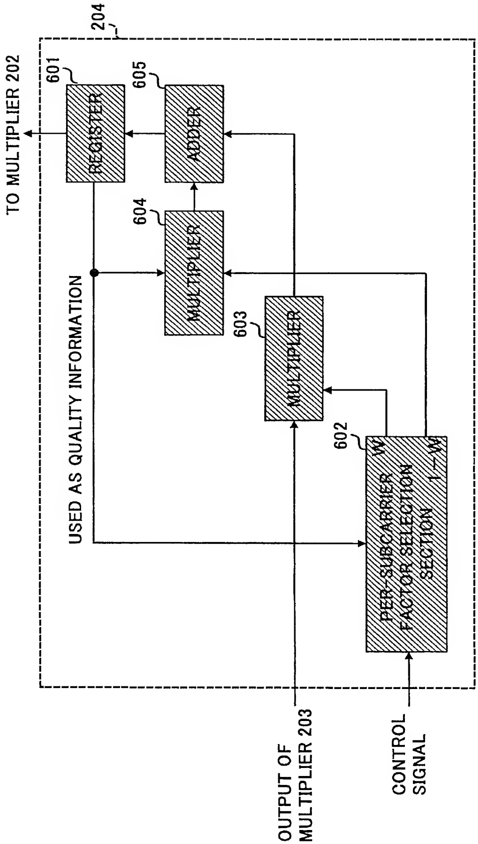

204
TO MULTIPLIER 202
601
REGISTER
605
ADDER
604
MULTIPLIER
603
MULTIPLIER
USED AS QUALITY INFORMATION
602
PER-SUBCARRIER FACTOR SELECTION SECTION
W
1−W
OUTPUT OF MULTIPLIER 203
CONTROL SIGNAL

FIG.8

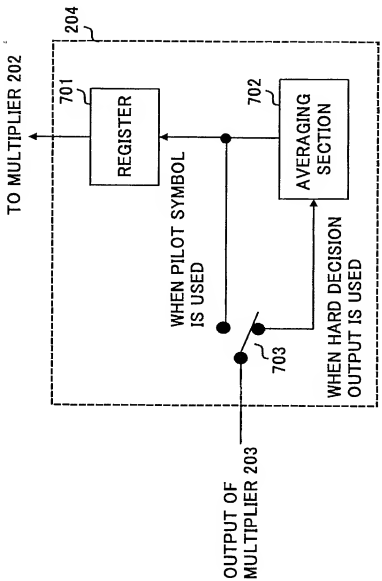

TO MULTIPLIER 202
204
701
REGISTER
702
AVERAGING SECTION
WHEN PILOT SYMBOL IS USED
WHEN HARD DECISION OUTPUT IS USED
703
OUTPUT OF MULTIPLIER 203

FIG.9

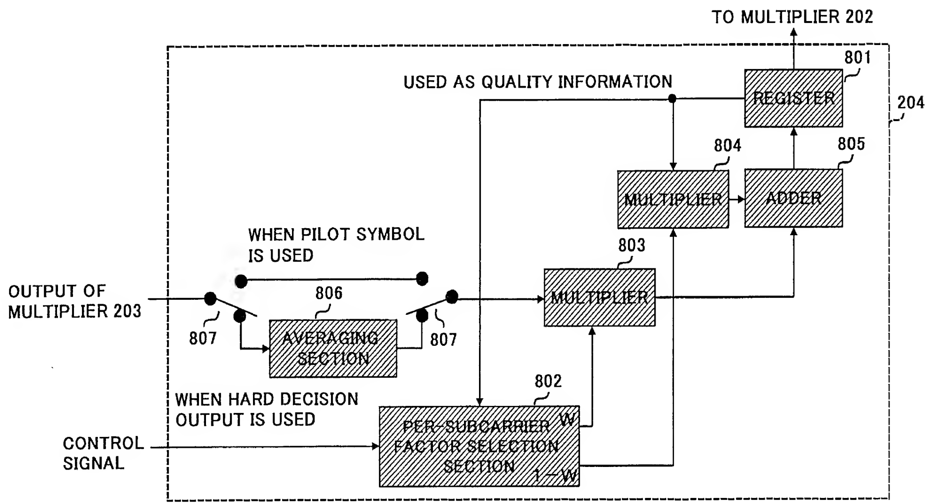

TO MULTIPLIER 202
801
REGISTER
204
USED AS QUALITY INFORMATION
804
MULTIPLIER
805
ADDER
803
MULTIPLIER
WHEN PILOT SYMBOL
IS USED
OUTPUT OF
MULTIPLIER 203
806
AVERAGING
SECTION
807
807
WHEN HARD DECISION
OUTPUT IS USED
802
PER-SUBCARRIER
FACTOR SELECTION
SECTION
W
1−W
CONTROL
SIGNAL

FIG.10

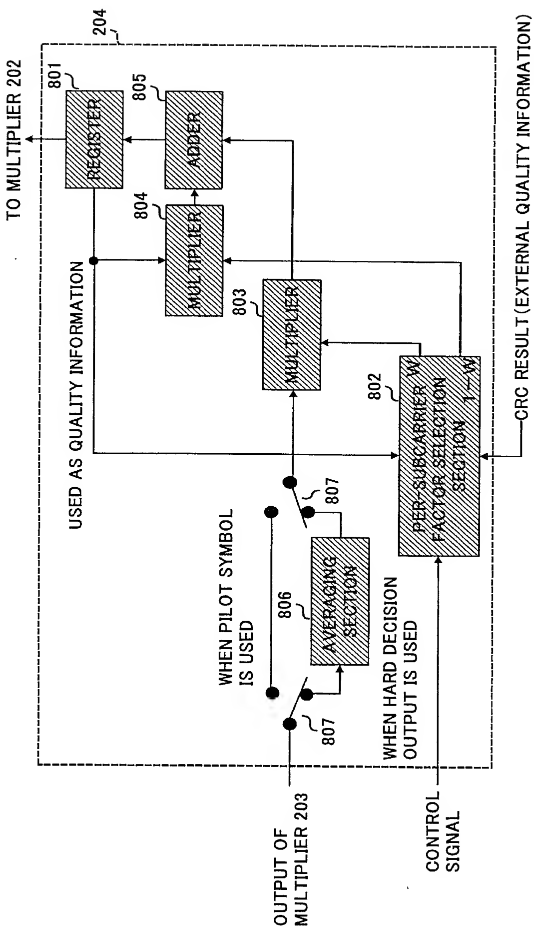

204
TO MULTIPLIER 202
801
REGISTER
805
ADDER
804
MULTIPLIER
803
MULTIPLIER
USED AS QUALITY INFORMATION
802
PER-SUBCARRIER FACTOR SELECTION SECTION
W
1−W
CRC RESULT (EXTERNAL QUALITY INFORMATION)
807
806
AVERAGING SECTION
WHEN PILOT SYMBOL IS USED
WHEN HARD DECISION OUTPUT IS USED
OUTPUT OF MULTIPLIER 203
CONTROL SIGNAL

FIG.11

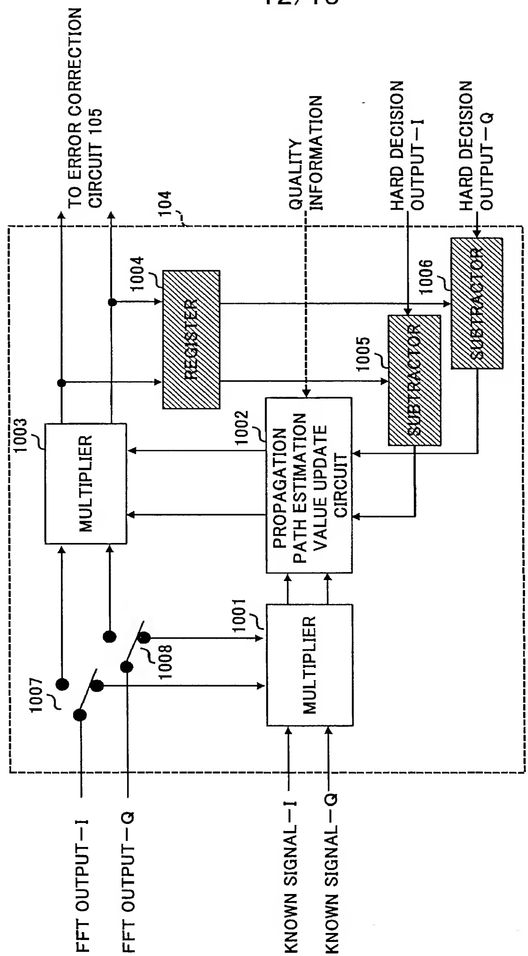
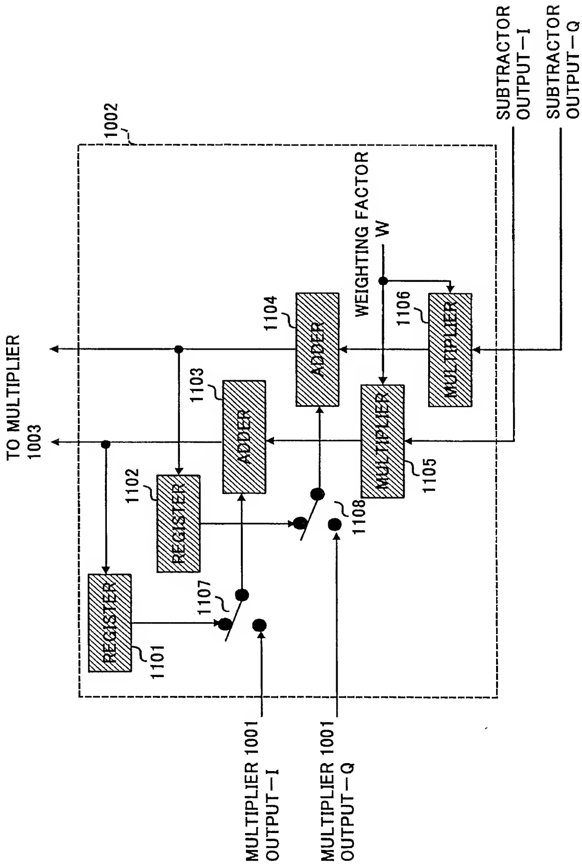

TO ERROR CORRECTION CIRCUIT 105
104
QUALITY INFORMATION
HARD DECISION OUTPUT－I
HARD DECISION OUTPUT－Q
1004
REGISTER
1006
SUBTRACTOR
1005
SUBTRACTOR
1003
MULTIPLIER
1002
PROPAGATION PATH ESTIMATION VALUE UPDATE CIRCUIT
1001
MULTIPLIER
1007
1008
FFT OUTPUT－I
FFT OUTPUT－Q
KNOWN SIGNAL－I
KNOWN SIGNAL－Q

FIG.12



1002
TO MULTIPLIER 1003
WEIGHTING FACTOR W
SUBTRACTOR OUTPUT-I
SUBTRACTOR OUTPUT-Q
1104
ADDER
1106
MULTIPLIER
1103
ADDER
1105
MULTIPLIER
1102
REGISTER
1101
REGISTER
1107
1108
MULTIPLIER 1001 OUTPUT-I
MULTIPLIER 1001 OUTPUT-Q

FIG.13

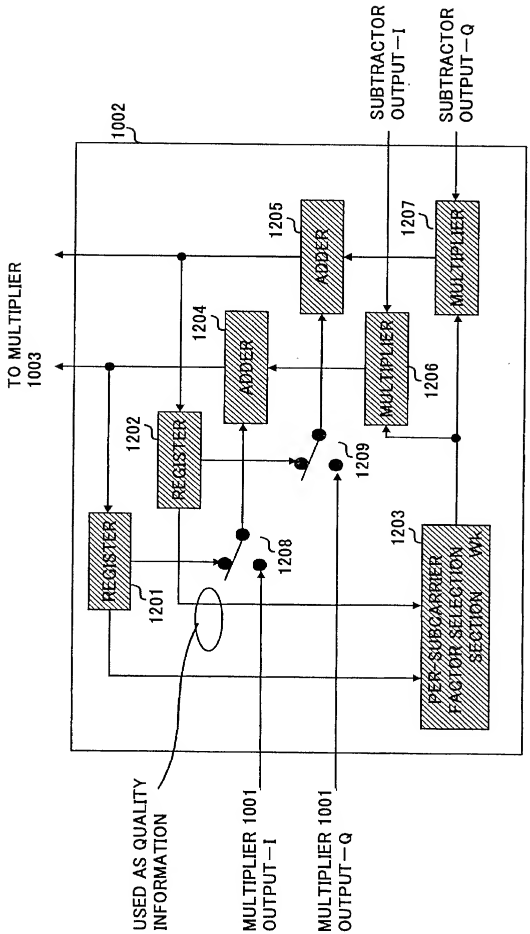

1002
SUBTRACTOR OUTPUT－I
SUBTRACTOR OUTPUT－Q
TO MULTIPLIER 1003
1205
ADDER
1207
MULTIPLIER
1204
ADDER
MULTIPLIER
1206
1202
REGISTER
1209
REGISTER
1201
1208
1203
PER-SUBCARRIER FACTOR SELECTION SECTION Wk
USED AS QUALITY INFORMATION
MULTIPLIER 1001 OUTPUT－I
MULTIPLIER 1001 OUTPUT－Q

FIG.14

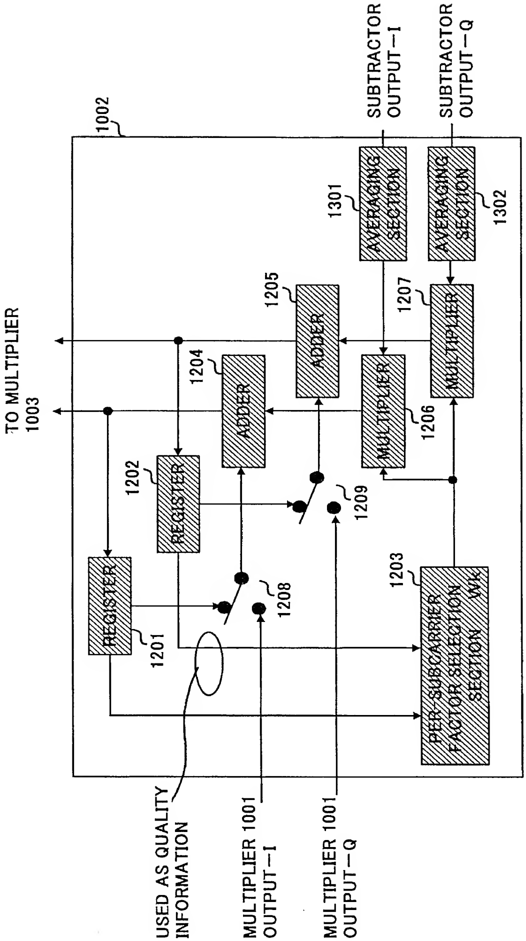
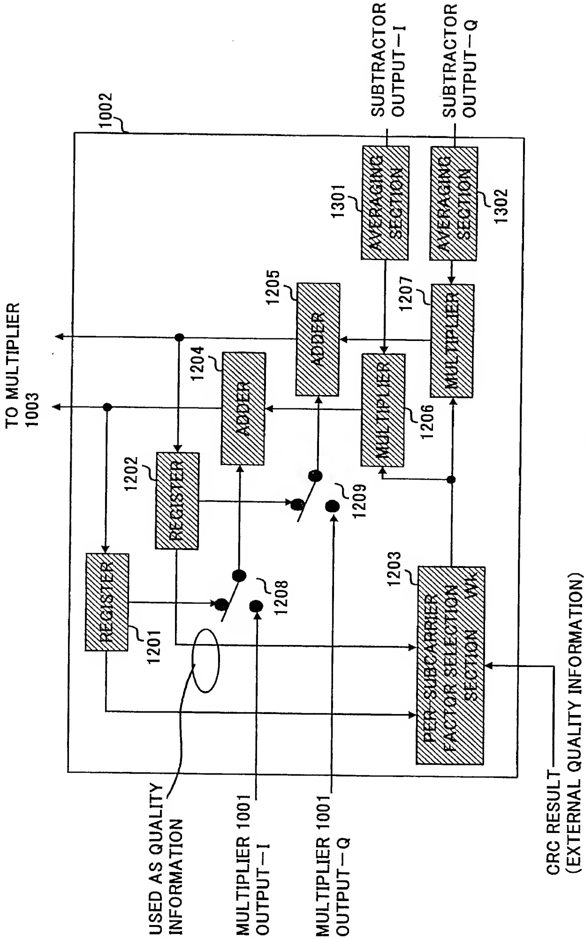

1002
SUBTRACTOR OUTPUT−I
SUBTRACTOR OUTPUT−Q
AVERAGING SECTION
1301
AVERAGING SECTION
1302
TO MULTIPLIER 1003
1205
ADDER
1207
MULTIPLIER
1204
ADDER
MULTIPLIER
1206
1202
REGISTER
1209
REGISTER
1201
1208
1203
PER-SUBCARRIER FACTOR SELECTION SECTION Wk
USED AS QUALITY INFORMATION
MULTIPLIER 1001 OUTPUT−I
MULTIPLIER 1001 OUTPUT−Q

FIG.15



TO MULTIPLIER 1003
1002
SUBTRACTOR OUTPUT—I
SUBTRACTOR OUTPUT—Q
AVERAGING SECTION
1301
AVERAGING SECTION
1302
ADDER
1205
ADDER
1204
MULTIPLIER
1206
MULTIPLIER
1207
REGISTER
1202
REGISTER
1201
1208
1209
PER-SUBCARRIER FACTOR SELECTION SECTION Wk
1203
USED AS QUALITY INFORMATION
MULTIPLIER 1001 OUTPUT—I
MULTIPLIER 1001 OUTPUT—Q
CRC RESULT (EXTERNAL QUALITY INFORMATION)

FIG.16

APPLICATION FOR UNITED STATES PATENT
Declaration for Patent Application

As a below named inventor, I hereby declare that:

My residence, post office address and citizenship are as stated below next to my name.

I believe I am the original, first and sole inventor (if only one name is listed below) or an original, first and joint inventor (if plural names are listed below) of the subject matter which is claimed and for which a patent is sought on

the invention entitled: OFDM COMMUNICATION APPARATUS AND PROPAGATION PATH ESTIMATION METHOD

the specification of which 2 (file no ______________)

(check at least one)
3 [x] is attached hereto
4 [ ] was filed on __________ as (5) U.S. Application Serial No.__________
6 [ ] and was amended ______________________
(if applicable)

Use this portion only if you are entering the U.S. National phase based on a PCT International Application designating the U.S.

7 [x] was filed as PCT international application

8 Number PCT/JP00/05599

9 on August 22, 2000

and was amended under PCT Article(s) 19 and/or 34

10 on ______________________ (if applicable).

11 priority date claimed in PCT International Application

(Country)	(Number)	(Day/Month/Year Filed)
JAPAN	H11-245299	31/August/1999

I hereby declare that I have reviewed and understand the contents of the above-identified specification, including the claims, as amended, by any amendment referred to above.

I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me which is material to patentability in accordance with Title 37, Code of Federal Regulations, §1.56.

I hereby claim foreign priority benefits under Title 35, United States Code, §119 of any foreign application (s) for patent or inventor's certificate listed below and have also identified below any foreign application(s) for patent or inventor's certificate or any PCT international application(s) designating at least one country other than the United States of America filed by me on the same subject matter having a filing date earlier than that of the application(s) on which priority is claimed.

12a Prior (Foreign) Application(s) any Priority Claims Under 35 U.S.C. 119 — Priority Claimed

(Country)	(Number)	(Day/Month/Year Filed)	[ ] Yes	[ ] No
(Country)	(Number)	(Day/Month/Year Filed)	[ ] Yes	[ ] No

Priority Claim(s) from U.S. Provisional Application(s) – I hereby claim the benefit under Title 35, United States Code, §119(e) of any United States provisional application(s) listed below:

12b

Application No.	Day/Month/Year Filed	Application No.	Day/Month/Year Filed

Do not use this portion to identify a PCT application if the parent application is the U.S. National phase of the PCT application

I hereby claim the benefit under Title 35, United States Code, 120 of any United States application(s) or PCT international application(s) designating the United States of America that is/are listed below and, insofar as the subject matter of each of the claims of this application is not disclosed in that/those prior application(s) in the manner provided by the first paragraph of Title 35, United States Code §112, I acknowledge the duty to disclose to the United States Patent and Trademark Office all information known to me to be material to patentability as defined in Title 37, Code of Federal Regulations, §1.56 which became available between filing date of the prior application and the national or PCT international filing date of this application.

13 (U.S. Application Number) (U.S. Filing Date) Status (patented, pending, abandoned)

I hereby appoint the following attorneys of the firm of Stevens, Davis, Miller & Mosher, L.L.P. as my attorneys of record with full power of substitution and revocation to prosecute this application and to transact all business in the Patent and Trademark Office:

James E. Ledbetter, Reg. No. 28732; Thomas P. Pavelko, Reg. No. 31689; and Anthony P. Venturino, Reg. No. 31674.

ALL CORRESPONDENCE IN CONNECTION WITH THIS APPLICATION SHOULD BE SENT TO STEVENS, DAVIS, MILLER & MOSHER, L.L.P., 1615 L Street, N.W., Suite 850, Washington, D.C. 20036, TELEPHONE (202) 408-5100, FACSIMILE (202) 408-5200.

See page 2 for signature lines

other side for instructions for completing this form

INSTRUCTIONS FOR COMPLETION OF THIS FORM

line 1 Insert the same title as is used on the specification and in the assignment.

line 2 Is optional but is provided so that you can use it to identify more readily an application prior to the time that the Patent Office application serial number is assigned. We suggest that the specification, drawings and declaration always bear a file number since it can help to get the papers together in case they become inadvertently separated. In instances where the specification is filed without a signed declaration form (under 37 CFR §1.53) a file number on a later-received separate form will assist us in associating it with the correct case.

line 3 Check this box if the specification, claims and drawing (if any) are attached to this declaration form, e.g., when filing a new patent application.

lines 4-5 Are only used in an instance where the application is already on file and the declaration from is being separately filed, e.g.,when the application was originally filed without a signed declaration or where the Patent Office has required a new declaration because of a deficiency in the original declaration. In such an instance the Patent Office will require that lines 4 and 5 be completed with the filing date and application serial number already assigned.

line 6 Is used in conjunction with line 5 but only when there have been one or more amendments to the specification or claims. Line 6 is also used when the Examiner requires a new declaration because claims inserted by amendment cover subject matter not originally claimed (37 CFR §1.67).

lines 7-11 Are for PCT (Patent Cooperation Treaty) cases and are used <u>only</u> when you are entering the U.S. National phase (Chapter I or II) based upon a previously filed PCT International application designating the U.S.

line 7 Check this box if this is a PCT National Phase application.

line 8 Insert PCT International application number.

line 9 Insert date of filing of PCT International application.

lines 10-11 Insert the date of all amendments filed in the PCT International application. Such amendments are optional, so this line at times will not be used.

line 12a Is used in the following instances:

(i) If a single priority is being claimed from a foreign application you need to list only the first-filed application; you do not need to list other countries if all applications were filed within one year of the U.S. filing.

(ii) If multiple priorities are being claimed, from a plurality of applications filed in one or more countries, you must list the first filed application for each aspect of the invention. Example: if aspect A of the invention was disclosed in an application filed 11 months earlier in country X and aspect B was disclosed 9 months earlier in an application filed in country Y, then the applications in <u>both</u> countries X and Y must be identified. Only the <u>first</u> application for each aspect of the invention needs to be identified <u>provided</u> all applications on that aspect were filed within one year prior to the U.S. filing.

(iii) If a <u>non-priority</u> application is being filed you must list <u>all</u> applications in all countries where corresponding foreign applications were filed <u>more than one year</u> prior to the U.S. filing. This is so the Examiner can check to see if any of those applications were published or patented early enough to be prior art against the U.S. application.

(iv) If there are more than two applications to be listed we suggest that you type in on this form only "See attached Schedule A" and then list all of the previous applications on an attached sheet.

line 12b Is used to claim priority under 35 USC §119(e) based on a provisional application filed within one year of the filing of the instant application. More than one provisional application may be identified provided neither was filed more than one year earlier.

line 13 This block is used only in instances where there is a previously filed <u>U.S.</u> non-provisional application which was copending at the time the present application was (or is being) filed. that previous application could be a U.S. non-provisional application or the National Phase of a PCT allocation. In such a case the present application may be entitled to the priority of the previous application's U.S. filing date (and consequently the foreign priority thereof) provided the present application is identified as a continuing application (continuation, divisional or continuation-in-part) of the earlier (parent) application. If the foregoing is applicable, please fill in one line for each such prior application.

line 14 Type the inventor's proper legal name in the order specified, e.g., "John B. JONES" or "J. Bob JONES" if the inventor so prefers. It is <u>not</u> acceptable to use only initials such as "J. B JONES."

line 15 The inventor's "signature" may be his (or her) usual manner of signing but it is preferable that the inventor simply write his (or her) name in his (or her) own cursive handwriting in the same order as on line 14, e.g., given name, middle initial and Family name.

line 16 Insert the <u>actual</u> date of signature.

line 17 Insert simply the city and state or country, e.g., "Paris, France", of the inventor's <u>residence</u>, not citizenship. No street address or postal code is required on this line.

line 18 Insert the inventor's citizenship. The statement of citizenship (or subject of) is a statutory requirement (35 USC §115). Simply the name of the country of citizenship, e.g., "Japan" is sufficient.

line 19 Insert the inventor's mailing address. The purpose of requiring the post office address is to enable the Patent Office to communicate directly with the inventor if desired, such as in the case of death of the U.S. attorney. It should be the address where the inventor customarily receives his (or her) mail and should include the postal code. If applicable it can be the inventor's business address or address at place of employment.

Applicants are reminded that the U.S. Patent and Trademark Office has very strict requirements as to proper execution of an application. The applicant should make sure that he reviews the declaration, prior to signing to make sure the declaration properly identifies the application and all relevant information; and should review the specification and claims (including drawings, if any) before signing the declaration. Failure to do so will require the filing of a supplemental declaration --- 37 CFR §1.67(c).

Any handwritten changes to the specification, claims or drawings must be in ink personally by all of the inventors <u>prior to</u> signing the declaration and the adjacent left margin must be initialed and dated by all of the inventors, e.g., "JBJ 6-9-91".

Please let us know if there are any questions regarding proper completion of this form. Thank you.

An assignment, a separate document requiring separate signature and dating may be enclosed. Please look for it and sign and date it in the same manner as in lines 15 and 16 above.

STEVENS, DAVIS, MILLER & MOSHER, L.L.P.

I hereby declare that all statements made herein of my own knowledge are true and that all statements made on information and belief are believed to be true, and further that these statements were made with the knowledge that willful false statements and the like so made are punishable by fine or imprisonment, or both, under Section 1001 of Title 18 of the United States Code, and that such willful statements may jeopardize the validity of the application or any patent issuing thereon.

PAGE 2 OF U.S.A. DECLARATION FORM

14a	Typewritten Full Name of Sole or First Inventor	1-00 Daichi		IMAMURA
		Given Name	Middle Name	Family Name
15a	Inventor's Signature	Daichi		Imamura
16a	Date of Signature	January	25	2002
		Month	Day	Year
17a	Residence	Yokosuka-shi JP	Kanagawa	JAPAN
		City	State or Province	Country
18a	Citizenship	JAPAN		
19a	Post Office Address (*Insert complete mailing address, including country*)	6-2-401, Hikari no Oka, Yokosuka-shi, Kanagawa 239-0847 Japan		
14b	Typewritten Full Name of Sole or First Inventor			
		Given Name	Middle Name	Family Name
15b	Inventor's Signature			
16b	Date of Signature			
		Month	Day	Year
17b	Residence			
		City	State or Province	Country
18b	Citizenship			
19b	Post Office Address (*Insert complete mailing address, including country*)			
14c	Typewritten Full Name of Sole or First Inventor			
		Given Name	Middle Name	Family Name
15c	Inventor's Signature			
16c	Date of Signature			
		Month	Day	Year
17c	Residence			
		City	State or Province	Country
18c	Citizenship			
19c	Post Office Address (*Insert complete mailing address, including country*)			
14d	Typewritten Full Name of Sole or First Inventor			
		Given Name	Middle Name	Family Name
15d	Inventor's Signature			
16d	Date of Signature			
		Month	Day	Year
17d	Residence			
		City	State or Province	Country
18d	Citizenship			
19d	Post Office Address (*Insert complete mailing address, including country*)			

*Note to Inventor: Please sign name on line 15 exactly as it appears in line 14 and insert the actual date of signing on line 16. If there are more than four inventors, please add a copy of this page for identification and signatures for the additional inventors.